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STEERING COLUMN AND SEAT BELTS EQUIPPED WITH SAFETY DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part application of co-pending international application number PCT/DE 98/00694

- filed 03/10/98 and claiming the priority of DE 19711392 C1 filed 03/19/97 and
- refiled 08/29/98 as revision by including the amended claims to reduce the number and the opposition against EP 0234003 A1 (DE 3605599 A1) and DE 3627558 C1 ref. to the German examination report of 01/29/98 and against DE 3536393 A1, DE 3736949 A1, DE 4106480 A1, WO 85/01709 (DE 3337231 C1) and WO 90/14253 ref. to the preliminary PCT examination report of 08/13/98

The abbreviations DE and EP denote the German Pat. Application or Document and European Pat. Appl. or Doc., which will be omitted hereinafter.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

It is an object of the present invention to arrange two independently operating piston devices of an energy-absorbing safety device in the front section of vehicle body in order to

- collapse the steering column,
- pre-tension the seat belts (safety belts) and absorb the pretensioning force

in any front collision thus ensuring the survival chance either in co-operation with front airbags or in the event of failure of front airbags.

2. Description of the Related Art:

It is known in the prior art to provide front airbags to softly cushion the head or a safety device to pre-tension the seat belts as well as to pull the steering wheel out of the head-injury area. Note, during the front collision the head of a driver belted, more particularly slackly belted or unbelted, is moving to the steering wheel defined by the head-injury area. However, none of all these conventional configurations takes into account their limitation and failure of passenger protection in real collision outlined hereinafter:

- false deployment of front airbags of three different test cars in the 40 % offset test against a deformable barrier (Stiftung Warentest 4/95 and Spiegel 13/95),
- false deployment of front airbags of Swedish cars from the same model activated by driving over bumps or surface irregularities of road (WK abbreviated for Wiesbadener Kurier of 10/01/94),
- false deployment triggering burns of the 1st and 2nd degree which a female driver of a Swedish car suffered in a real front collision (WK of 07/14/95),
- severe injuries due to non-deployment of side airbags in a real side collision of a police car against an electrical utility pole (AMS abbreviated for Auto Motor and Sport 12/96 pp. 50),
- severe injuries of a racer due to the non-deployment of front airbag in spite of big expenditures of manufacturing and assembling (AMS 14/96 pp. 190 to191),
- a baby beheaded by the impact of front airbag falsely deployed in a rear collision of a German car reversing into another vehicle at a parking lot in Boise of US-State Idaho (WK of 11/29/97) and

- false deployment triggering fatal neck injury of co-driver (front passenger) and heavy injury of female driver (see problem "oop" in Chap. II), but minor injuries of four occupants of the other vehicle when both German cars collided at speeds of approx. 60 and 100 km/h (Spiegel 29/1996).

Regardless of R&D work since about 1970 the unreliable operation of airbags and sensors has been substantiated by false deployment and two expensive recall programs of a German car manufacturer to recheck the plug connection of the front airbag of co-driver in February and April 1995.
The German Magazine "Spiegel" of 29/1996 disclosed the discussion of an accident-expert with a world-wide renown German car manufacturer building the safest cars and a well-known manufacturer of airbags and sensors in the following summary:

"False deployment makes the airbag a device whose function to save life must be seriously questioned. The wide-spread installation of airbags increases false deployments. The subject of false deployment is known and should not be played down"

As a result from this problem case **F1**, there is a need to invent countermeasures in Chap. I, II and IV.

In order to pre-tension the seat belts operated by a belt pulley driven by an engine, the parts of a release device ref. to DE 3536393 A1 are force-locking connected with each other by a wire (pp. 6/col. 37 to 43) activated in the event of the deformation of a vehicle part. With the data n = 6000 U/min, radius of belt pulley = 10 mm and t = 20 ms lower than the deployment of BMW- Frontairbag of 22 ms the formula of safety belt-tension yields 20 mm, which is insufficient and is far less due to the slip-coefficient of the belt and the elongation of safety belt.
Recently, due to danger of fire in collision and/or rollover the engine is put out of operation by the interruption of the gasoline-supply and/or electric circuit.

A front bumper *S1* ref. to WO 90/14253 consists of a front part *V1*, whereto a row of rollers *V11* is attached, a rear part *H1*, whereto a row of rollers *H11* is attached, and a belt *B1* arranged between both rows of rollers *V11, H11*. Both ends of belt *B1* are rigidly attached to a pair of movable rollers *B2, B3* connected to safety belts by a belt *B4*. In arbitrary collision the front rollers *V11* move in the spaces of rear rollers *H11* displacing the belt *B1* thus changing the position of both rollers *B2, B3* whose belt *B4* pulls the safety belts. This safety device is characterized by the following shortcomings:

- The front bumper *S1* is enormously large and heavy.
- In contrary to any conventional bumper designed to absorb small energy e.g. in the event of collision against a wall during parking, repair costs are incurred due to the damage of the front bumper *S1*.

The clamping device ref. to DE 4106480 A1 consists of a guide part *A1* to deflect a wire *A3* backwards, provided for pre-tensioning belts, and a part *A2* to loosely retain that wire. In the ideal loading case in y-direction in the event of mid-front collision the relative movement between both moving parts *A1, A2,* expected to pre-tension belts, is less than the specification of the feature due to the deformation of the part *A2* in y-direction too.
In real arbitrary collision the runner 30, whereto both parts *A1, A2* are attached, is deformed in arbitrary direction, hence, it can always occur that the length of the curved-deformed section *A1, A2* of the runner is unchanged, thus resulting in failure of belt-pre-tensioning.

Ref. to the safety device of EP 0234003 A1 for vehicle having mid- or rear-engine a pair of longitudinal members (impact elements **5**) movable in both runners pulls the belt reels to pre-tension the safety belts. Due to lack of energy absorber and delimiter the passengers are exposed to large acceleration of those members (see problem cases **F4, F5**), strangulation resulted from unlimited pulling the belts and oscillation.
Moreover, the design of impact elements into one of applicable 13 embodiments in **Fig.** 1 to 11 is difficult.

Ref. to the safety device of DE 3627558 C1 three wires, activated by the intrusion of the power plant in mid-front collision, pull the steering wheel **90** out of the head-injury area and tension all seat belts **64**, the passengers are subjected to severe/fatal injuries due to

- large acceleration, strangulation and oscillation in real mid-front collision (front collision without offset) or
- failure of the safety device in arbitrary offset front collision.

The shortcomings of the features of DE-OS 1655597, DE 3536393 A1, DE 3736949 A1, DE 4106480 A1, WO 85/01709 and WO 90/14253 are similar to EP 0234003 A1 and DE 3627558 C1

In an advantageous further development of EP 0234003 A1, DE 3627558 C1, WO 85/01709 A1 and DE 3736949 A1 of the inventor AUDI/VW, a safety device ref. to DE 3801347 C2, under the trademark "procon-ten", abbreviation from programmed contraction-tension, is achieved to have protected occupants against severe and fatal injuries only in the event of mid-front collision because the carrier rod **201** of the power plant **10** in **Fig.** 5 pre-tensions

- the wire **208** via pivots **204, 205, 206** to pre-tension both seat belts **64** in S_G-direction and
- the wire **209** via both pivots **204, 205** to pull the steering wheel **90** out of the head-injury area in S_L-direction.

The steering column **91** (precisely: the casing of the steering column) with a collapsible (compressible), energy-absorbing steering part **91.1** is fastened to a mounting girder **56.1** of passenger compartment **56** in **Fig.** 2.
The following problem cases cast doubt on the applicability of the safety device "procon-ten":

Problem case **F2**: For years R&D work has been focused on

- developing compact cars suitable for daily driving to workplace and meet customers, for resolving the problems of increasing traffic density and finding a parking lot as well as for lowering the fuel consumption to under 4 l/100 km and
- improving the passenger protection to pass increasingly difficult EU and US-crash tests. According to the 1st step of the EU front crash test valid since Oct. 95, the vehicle is crashed at 50 km/h against a 100 % offset-barrier with an impact area having a 30° inclination and two vertical bars to prevent from transversely gliding. Subsequently, according to the 2nd step, succeeding the 1st step, valid from the beginning of Oct. 98, the vehicle is crashed at 55 km/h against a deformable 40 % offset-barrier. Hence, these simulation tests correspond more and more to the real collision of two vehicles.

In comparison with a small car VW Polo ® with length x height x width = 3.71 x 1.42 x 1.66 m any compact car has a shorter length such as MB (Mercedes Benz) A-Class ® with 3.58 x 1.56 x 1.72 m. Because of the extremely short front section of vehicle structure, during the front collision the power-plant **10** ref. to DE 4326396 A1 or US Pat. No. 5492193 in **Figs.** 2 and 3 slides along the sliding wall **55** for the purpose of displacement below the passenger compartment while the rearward mounts **22** of auxiliary frame **65** are detached from both runners **30**. Owing to this power-plant displacement as well as ref. to DE 2246077 C2, DE 3301708 C2, DE 4405904 C1 the power-plant is prevented from intrusion into passenger compartment.

The power-plant release ref. to DE 19636167 C1 is superior to that power-plant displacement because one or both runners **30** are not subjected anymore to the kinetic energy of the power-plant **10** after the release of that power-plant, thereby able to absorb more impact energy.

Problem case **F3**: Among the four collision types ref. to the study "vehicular safety in 1990s" issued by Institute of Vehicle Safety (similar to NHSTA, both offices work together), a Department of GDV (German Insurance Association) in Munich, the collision type "mid-front collision" shows a low percentage of 19.3 % regarding fatal injuries.

Problem case **F4**: Oscillation of the upper part of body due to undamped energy absorption in front- or rear collision. In the crash tests accomplished by the Institute of Vehicle Safety in co-operation with Technical University in Graz, Austria for the purpose to simulate a real rear collision, in 40 ms the torso is moved forward out of the back rest unit while the initial position of the head in unchanged. In 100 ms the head is accelerated about the rotation point H in the direction w_H. In 130 ms the head contacts the head rest. The pitch acceleration $\ddot{U}_H$ reaches the maximum. A rebound (repeat of forward motion) of the upper part of body occurs in 200 ms. Despite the low speed 8.5 km/h and acceleration 2.5 g in the crashtests of different nine vehicle seats the upper part of body oscillates. Among 22 volunteers one suffered minor cervical injury for two days and some minor pain for one to two days.

Publication of GDV: Order Nr. 9609 "Neck Injuries in Car Accidents...";

Problem case **F5**: Attributed to the enormously less capacity of energy-absorption of the carrier rod **201** in comparison with both runners **30** the seat belts connected to both ends of wire **208** are accelerated in magnitude far higher than the peak acceleration of runners at 60 m/s^2. See Fig. 1 of DE 3826958 A1. The energized belts endanger life of the occupants, particularly, of the fetus of pregnant female occupant.

In comparison with deformable element **1** ref. to DE 19615985 C1 in **Figs.** 1, 6 the carrier rod **201** has far less capacity of energy-absorption. Due to this shortcoming in mid-front collision against a stiff column e.g. of highway the power-plant **10** intrudes into passenger compartment in excess of the displacement u_0, thereby resulting in severe and fatal injuries.

Problem case **F6**: The carrier rod **201** is designed for five operations of limitation, energy-absorption, part of engine suspension, wire-adjuster and motion transmitter for both wires **208, 209**. The controversy of different targets is explainable.

As deformable elements ref. to DE 4224489 A1 and DE 3826958 A1 both front portions of longitudinal runners in association with the front section of vehicle structure convert the front impact energy into deformation work to reduce the acceleration. Owing to the greatest stiffness ref. to DE 3826958 A1 the rear section of front portion facing the passenger compartment (cell) is less or hardly deformed in comparison with to the front section of that front portion under load. This rear section is subdivided into a number of zones Z_{n-2}, Z_{n-1}, Z_n, Z_{n+1}. Each deformable element with the length L_E in **Fig.** 10 is subdivided into n crumpling zones Z_1, Z_2, .. , Z_a, .. , Z_b, .. , Z_c, .. , Z_d, .. , Z_n, Z_{n+1}. Ref. to DE 19615985 C1 greater stiffness can be achieved by integrating additional elements **3a, 3b, 3c , 3d** in **Figs.** 2 to 4, 7 , 9 and 10 in order to avoid to a great extent an interruption of the time-dependent curve of acceleration by controlling the deformation behaviour during the folding and buckling as the result of zones with variable stiffness and by optimizing the crush behaviour of the vehicle frame ref. to DE 19615985 C1.

Ref. to DE 19615985 C1 and DE 19636167 C1 the independently operating mechanisms deform their respective deformable elements **1** in the event of arbitrary front collision in order to increase of the passenger protection and exploit of the material in association with the design of a compact car, power-plant release and optimization of the crush behaviour. Basically, every mechanism consists of a guide element **52**, a bearing box **30.7** to guide at least one impact element **5** whose first terminus is fixedly attached to the guide element **52** by connection elements **1.5** and whose other terminus to the impact pan **5.1, 5.1a** by connection elements **1.5**. For the purpose of energy-absorption the deformable element **1** can be defined by honey-comb energy-absorbing parts **1.8**. The bearing box **30.7, 30.7a** is arranged to or in at least one vehicle girder such as runner **30** and/or transverse girder **31**. However, it is possible to assemble several impact elements **5, 5d** in each vehicle half in **Fig.** 7 or in each bearing box ref. to DE 19615985 C1. Under load of front impact energy every cone- or torus-shaped hub **5.3** of impact pan **5.1a** ref. to DE 19636167 C1 centres the impact pan to enhance the efficiency of material exploitation by bulging out the runner **30** during the folding. The profile of impact pan **5.1, 5.1a** is arbitrary.

SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is to guarantee the survival chance in the event of arbitrary front collision by optimizing the method of operation of the safety device provided with wires, pivots (pivotal rollers) and energy-absorbing limitation-units.

This principle and other objects of the present invention and of the aforementioned problem cases **F1 to F6** are accomplished by the following features (proposals):

- minimize the time consumption by arrangement of the space-saving impact element in and/or to the stiff vehicle girder, less or hardly deformed under load of impact energy, such as transverse girder **31**, side rail **34**, mounting girder **56.1**, sliding wall **55**, passenger compartment **56** and/or one of crumpling zones Z_a, Z_b, Z_c, Z_d, Z_{n-2}, Z_{n-1}, Z_n, Z_{n+1} of runner **30**.
- optimize the operation of the safety device comprising e.g. a pair of impact elements **5** with impact pans **5.1, 5.1a**, a pair of guide elements **52**, a pair of delimiters (limiting units) **51** and a pair of deformable elements **1** in **Figs.** 1 and 6:

1. at least one pair of independently operating impact elements **5, 5a to 5d, 5c1, 5e1 to 5e4** in front section of vehicle structure to independently displace their guide elements **52, 52a** in arbitrary front collision in **Figs.** 1 to 3, 6 to 10:
   * In offset front collision (F > $\underline{F}$) the impact element **5** is responsible for the displacement along the y2-axis, in case $\underline{F}$ > F the other impact element **5** along the $\underline{y2}$-axis.
   * In mid-front collision (F = $\underline{F}$) both impact elements **5** are responsible for their displacements along the y2- and $\underline{y2}$-axis.
2. increase of energy absorption by runner **30** and/or deformable elements **1** to lower the acceleration of passenger compartment.
3. at least two pairs of energy-absorbing limitation-units **70, 80, 80a to 80e** with sites of predetermined fracture "b" in **Figs.** 12 to 21
   * to limit the pre-tensioning force and
   * to lower the acceleration of seat belts **64**.
4. separate the pre-tensioning operation the seat belts in S_0-direction from the operation to pull the steering wheel in S_1- as well as S_2-direction.
5. limit the forward movement of steering wheel by means of at least one pair of delimiters **51, 51a** with sites of predetermined fracture "b".
6. design safety device for any vehicle either with present engine suspension or with power-plant displacement or with power-plant-release.

- a plurality of adjusting possibilities in Chap. V and VI.

In the 1st to 2nd embodiments in **Figs.** 1 and 6 two safety devices for new vehicle are provided with their corresponding bearing boxes **30.7, 30.7a** to independently deform their corresponding deformable elements **1**. However, these devices can operate without deformable element. Owing to both bearing boxes to guide the impact elements **5** with impact pans **5.1, 5.1a** both guide elements **52** displace precisely and independently. Hence, each safety device works precisely. Commonly, the application rate of invention is always judged on the applicability, not primarily for new vehicles, but for vehicles under the "tooling condition" in Chap. I. Although there is no space left in the front section of vehicle structure, the pair of impact elements **5a to 5d, 5c1** can be disposed therein in the following 3rd to 7th embodiments by space-saving arrangement:

- their first termini **5c** to the front portions of both runners **30** facing the power plant **10** in **Fig.** 2, their middle portions through both bearings **58c** of sliding wall **55** and both guide elements **52a** to their other termini.
- their first termini **5c1** to the front portions of both runners **30** facing the power plant **10** in **Fig.** 3, their middle portions through both bearings **58c1** of transverse girder **31** in **Figs.** 3, 3a and both guide elements **52a** to their other termini.
- their first termini **5d** to the lower front portions of both runners **30** in **Fig.** 7, their middle portions through both bearings **58d** of transverse girder **31** and both guide elements **52a** to their other termini.
- their first termini **5a** to the upper front portions of both runners **30** in **Fig.** 9, their middle portions through both bearings **58a** of transverse girder **31** and both guide elements **52a** to their other termini.

- their first termini **5b** to the upper front portions of both runners **30** in **Fig.** 10, their middle portions through both holes of transverse girder **31** as bearings **58b** and both guide elements **52a** to their other termini. Unfortunately, time is consumed for assembling the impact element **5b** in the runner **30** via bolt **54** and nut **54.2**. Whatever space problem exists in the front section of vehicle structure, impact elements can always be accommodated in the runners.

Any bearing of **58a to 58d, 58c1** can be attached to the rear portion of runner **30** and the guide element **52a** between both termini of impact element **5e1, 5e2**. Space of large vehicle, e.g. van, between the runner **30** and front tire can be exploited to accommodate any impact element **5e3, 5e4**. In the following 8th to 11th embodiments the impact elements **5e1 to 5e4** can be disposed in the front section of vehicle structure by space-saving arrangement (in **Figs.** not completely drawn, however, perceivable due to the similarity to the following 3rd to 7th embodiments):

- their first termini **5e1** to the front portions of both runners **30** facing the power plant **10** in **Fig.** 2, their other termini through both bearings **58c** of sliding wall **55** and both guide elements **52a** to their middle portions.
- their first termini **5e2** to the front portions of both runners **30** facing the power plant **10** in **Fig.** 3, their other termini through both bearings **58c1** of transverse girder **31** in **Figs.** 3, 3a and both guide elements **52a** to their middle portions.
- their first termini **5e3** to the front portions of both runners **30** facing the front tires in **Fig.** 2, their middle portions through both bearings **58c** of sliding wall **55** and both guide elements **52a** to their other termini.
- their first termini **5e4** to the front portions of both runners **30** facing the front tires in **Fig.** 3, their middle portions through both bearings **58c1** of transverse girder **31** in **Figs.** 3, 3a and both guide elements **52a** to their other termini.

The application rate of invention is substantiated by the generalized applicability for all vehicles listed in Chap. I. The profile of impact elements **5a to 5d, 5c1, 5e1 to 5e4** are arbitrary, however preferably, round or square due to low manufacturing costs.

At the arrangement of impact element **5b** in the deformable front portion of runner **30** in **Fig.** 10 the diameter of the hole of transverse girder **31** is machined bigger than the diameter of impact element in order to house a rubber bush **58.1** in **Fig.** 3a. Rubber bushes **58.1, 54.1** in **Fig.** 9 isolate noise and enhance the moving property of impact element during its displacement owing to the resilience under load. Accordingly, the other impact elements **5c, 5c1, 5d, 5b** are provided with rubber bushes at their attaching sites.

For the purpose of labour saving the hole of impact element **5b** is provided with rubber sleeve (not drawn) before assembling.

Each energy-absorbing limitation-unit **70, 80, 80a to 80e** in **Figs.** 1, 12 to 21 is designed to meet four functions in order to optimize the pre-tensioning condition of seat belts **64**:

- perform work of deflection and of friction to absorb (dissipate) impact energy, therefore, lowering the acceleration of seat belts,
- damp the vibration,
- limit (restrict) the pre-tensioning force of seat belts by fracturing the sites of predetermined fracture "b" when the blocking (limiting) condition is met in excess of a predetermined displacement and

- preserve the pre-tensioning force of seat belts by clamping force, surface properties of both members under load of clamping force and by engaging the following retaining parts with each other:
  * the retaining notch of tube **71.1** with the retaining plate **71.3** pivotally attached to both plates **71.4** and by spring element **71.5** pre-loaded in **Fig.** 12 or
  * the retaining hole of expanding clamping element **82a** with the two-sides-retaining strut **81.2a** of retaining element **81a** in **Figs.** 14, 15 or
  * the retaining collar **82.1b** of contracting clamping element **82b** with the retaining notch of retaining element **81b** in **Figs. 16 to 18.**

Hence, the pre-tensioning force of seat belts **64** in direction S_0 is limited, preserved and independent of the displacement of steering wheel **90** in direction S_1 as well as S_2.
As non-recurring limitation-unit **70** with delimiter **71** the use of spring element **72** and shock absorber (friction absorber) **73** is too expensive. In order to save costs and space the invention deals with limitation-units **80, 80a to 80e** each comprising a pair of clamping element / retaining element with delimiter. The clamping force (spring force) of each pair of clamping element / retaining element depends on the material, length denoted with l, longitudinally variable width of gap denoted with s, shape of the pair itself and spring rate of the clamping element expanded (flared) or contracted (squeezed) during its deformation along the cone-shaped portion of retaining element. Applying the same parameters on the design of pair and the cone-shaped portion of retaining element, the clamping force of pair **80** is less than of pair **80a** due to the cylinder form of clamping element **82** denoted with d_0. For the purpose of ideal contact with each other the portion **81.3a to 81.3e** of retaining element **81a to 81e** and the clamping element **82a to 82e** have the same conical form determined by the formula $(D_2\text{-}D_1)/L = (d_2\text{-}d_1)/l$ in **Figs.** 14 to 21. Owing to these features (proposals)

- the expansion or contraction of the clamping element increases the clamping force and
- the clamping element with gap is loosely guided by its retaining element during performing work of deflection and of friction.

Due to longitudinally contracting the circumference of clamping element with diameter D_2 and D_1 to an amount of e.g. 0.5 mm the clamping force of pair **80a, 80c** is increased accordingly.
Any one of limitation-units **80, 80a to 80e** under load of pre-clamping force can be pre-assembled by inserting

- and expanding the clamping element **82, 82a, 82c** with gap into the retaining element **81, 81a, 81c** or
- and contracting the clamping element **82b, 82d** with gap into the retaining element **81b, 81d.**

Owing to large friction coefficient (rough surface property), large contact area of clamping element with retaining element and wide expansion or contraction the clamping force is strong enough for pre-tensioning and retaining the seat belts, hence, enabling to design the cheapest limitation-unit **80e** without retaining and blocking parts in **Fig.** 21. It consists of

- a retaining element **81e** representing any one of elements **81, 81a to 81d** and
- clamping element **82e** representing any one of elements **82, 82a to 82d** without retaining and blocking parts, however, by use of blocking parts **60.6 to 60.8.**

For the purpose of sound-proofing the cone-shaped portion of retaining element **81, 81a to 81e** is surrounded by a sound-proof material **83** in **Fig.** 15. The work of friction depends on clamping force, surface property of both elements on contact and friction coefficient.
The work of deflection is achieved during the deformation of clamping element moved by towing force of wire **60** along the retaining element. Similar to spring element **72** and shock absorber **73** each pair of clamping element / retaining element performs work of deflection and of friction.

Summary of the advantages of the present invention:

I. Space-saving safety device to resolve the problem cases **F1 to F6** suitable for
  - vehicle with present engine suspension, prototype-vehicle or production model and new vehicle prior to the market-introduction such as MB A-Klasse ® in **Figs.** 2, 3 as well as vehicle in **Fig.** 5, noteworthy under the "tooling condition" that *no change of the tools and only a few modifications of vehicle frame are allowed*;
  - new vehicle with power-plant displacement ref. to DE 4326396 A1 (US-PS 5492193), DE 2246077 C2, DE 3301708 C2, DE 4405904 C1; or
  - new vehicle with power-plant release ref. to DE 19636167 C1 to prevent intrusion and to increase the energy absorption by both runners **30** and the large-area deformable elements **1** ref. to DE 19615985 C1.

II. Solution for the problem "oop" (out of position) and increase of the reliability of passenger protection in the event of real arbitrary front collision owing to the **minimal** time consumption or **quick** response by arrangement of at least one pair of independently operating impact elements in and/or to the runners, thus abundant time remains for pre-tensioning the seat belts **64 before** the full deployment of airbags and for lowering the belt-acceleration by means of energy-absorbing limitation-units. The safety device ref. to DE 3801347 C2 operates **only** in the event of mid-front collision (without offset) and **after** the deformation of runners, engine bearings, power plant and carrier rod. Much more time is consumed, hence, it is doubtful whether the remaining time is sufficient to execute the pre-tensioning operation. The start of pre-tensioning of the present belt pre-tensioners after 30 ms ref. to DE 3801347 C2 is too late due to the deployment time of 22 ms for both BMW front airbags with 62 and 135 litres ref. to AMS 14/96.
By means of adjusting holes in Chap. V and VI, offset of l_x and taut tolerances in Chap. III etc. a car manufacturer can determine the best strategy from the construction variations e.g.:
  - simultaneous start of pre-tensioning, pulling the seat belts and inflating the airbags and one airbag to softly cushion the driver when the collapsible steering part **91.1** is pulled (folded) forward and/or
  - use of a more reliable, but slower operating sensor by banning the sensors ref. to DE 4117811 C2, US Pat. No. 5282134 etc. which are enormously unreliable and pricey due to a high number of calculations within extremely short time and in succession, thereby boosting false deployment, manufacturing- and repair costs. One false deployment impoverishes the car owner by approx. DM 4000 for the renewal of a set of airbags and, additionally, endangers life of occupants and driver.

Within the abundant deployment time by prolonging the BMW deployment time e.g. to 44 ms and in case of failure of airbags and sensors, the advanced safety device always protects the occupants by pulling the steering wheel **90** out of the head-injury area, pre-tensioning the seat belts in short time, limiting the pre-tensioning force of seat belts,

damping the vibration and lowering the belt-acceleration until fracture of said sites of predetermined fracture takes place, whereafter that pre-tensioning force is preserved. All these features substantially guarantee the survival chance and improve the reliability in any front collision.

III. Determining the start of operation of the safety device by

- offset of l_x between the terminus of impact element **5** and the front portion of runner **30** denoted with $l_0 > 0$ or $l_1 \leq 0$ between the impact pan **5.1** and runner **30** in **Fig.** 1 or
- attaching one of the impact elements **5a, 5c, 5c1, 5d, 5e1 to 5e4** to or in one very stiff crumpling zone Z_a, Z_b, Z_c, Z_d in **Figs.** 2, 3, 7, 10

in order to avoid expensive repair in collision during parking or for the purpose of classifying the insurance class by calculating the damages. The start of the operation of the pre-tension of seat belts and the displacement of steering column can be set in offset and, furthermore, in association with adjusting holes in Chap. V and VI. Due to the extremely short remaining time an absolute tautness of wires **208, 209** ref. to DE 3801347 C2 pp. 2/col. 12 and pp. 4/col. 15 is necessary. On contrary, an absolute tautness of wires **61, 62** is not necessary. The permissibly taut tolerances for wires which are different can be exploited for the strategy for pre-tension and pull e.g. absolute tautness of wire **60** and less absolute tautness of wires **61, 62**.

IV. Low acceleration of seat belts during pre-tensioning by work of deflection and of friction performed by at least one pair of energy-absorbing limitation-units **70, 80, 80a to 80e** to resolve the problem case **F4**, particularly, in regard to the optimal protection of fetus against severe and fatal injury.

V. Use of wires **61, 62** with only two to four different wire lengths for the plurality of vehicle classes from A-, C-, E-, G-, M-, S-, X-, V-, Z- to van-class incl. the models of each class

- by compensating the length within the permissible tolerances via
  * adjusting holes $H_1, H_2, .., H_n$ of impact element **5d,**
  * adjusting holes $K_1, K_2, .., K_n$ of impact element **5a, 5b, 5d,**
  * adjusting holes $L_1, L_2, .., L_n$ and $N_1, N_2, .., N_n$ of delimiter **51** with site of predetermined fracture "b",
  * adjusting holes $N_1, N_2, .., N_n$ of delimiter **51a** with site of predetermined fracture "b",
- by clamping a spacer (fixture) **51.6a** with open profile and length f_1 to the wire **61,** preferably, in front of the blocking ring **51.4a** to correct the distance of f between the blocking ring **51.4a** and holder **51.5a** in **Fig.** 8. The spacer clamped in front of the blocking ring **51.4a** is drawn with dotted lines. The adjusting work can be done elsewhere (on the assembly line, in assembly hall or garage) upon allocation of a number of spacers **51.6a** with different lengths $f_1, f_2, .., f_m, f_n$.

VI. Use of wire **60** with only two to four different wire lengths for the plurality of the above-mentioned vehicle classes

- by compensating the length within the permissible tolerances via
  * adjusting holes $M_1, M_2, .., M_n$ of tube **71.1** or clamping element **82, 82a, 82b** to receive the end of wire **60** by use of wire holder **60.2**, securing parts **60.4** and pin **60.3b** (not drawn, but similar to the parts in **Fig.** 15) in **Figs.** 12 to 16,
  * adjusting holes $K_1, K_2, .., K_n$ of impact element **5a, 5b, 5d** in **Figs.** 7, 9, 10,
  * adjusting holes $N_1, N_2, .., N_n$ of delimiter **51c, 51d, 51e** with site of predetermined fracture "b" in **Figs.** 19 to 21,
- by clamping a spacer **60.6** with open profile and length g_1 to the pre-wire **60.1e**, preferably, in front of the blocking ring **60.7** to correct the distance of g between the blocking ring **60.7** and holder **60.8** fixed to the side rail **34** in **Fig.** 21. The process of clamping is illustrated by arrow. The adjusting work can be done elsewhere upon allocation of a number of spacers **60.6** with different lengths $g_1, g_2, .., g_m, g_n$.

VII. Use of the delimiter **51, 51a** with the same length by compensating the length within the permissible tolerances via adjusting holes $N_1, N_2, .., N_n$. The projection of the blocking pin **51.4** through one of the adjusting holes $N_1, N_2, .., N_n$ of the end portion of delimiter **51** determines the fracture at the site of predetermined fracture "b" upon the contact of that pin **51.4** with the holder **51.5** in **Fig.** 11. During the collapse of the steering part **91.1** to pull the steering wheel **90** under load of impact energy the fracture of that site occurs, thereby limiting and terminating the forward movement of that steering wheel.

VIII. Costs for manufacturing and storing parts are substantially saved by standardising the parts of safety device for different vehicles by means of a plurality of adjusting holes. Due to a single adjusting means by changing the position of pivot **204** along the carrier rod 201 and due to different vehicle sizes the wires of AUDI 80 would, presumably, not fit for AUDI A3 ® and A8 ®, contrary to the goal of invention of DE 3801347 C2. Compare this single adjusting means with five adjusting means for wires **61, 62** and at least three adjusting means for wire 60.

IX. Energy-absorbing limitation-units **80, 80a to 80e** are economical and space-saving, hence, suitable for seat belts of driver and co-driver or all occupants. Owing to space-saving design the limitation-units in series can absorb more impact energy.

X. Costs are cut by pre-assembling limitation-units **80, 80a to 80e** under load of pre-clamping force, by enlarging the tolerance zone and by quality control prior to delivery. In case of reject the position of the clamping element to the respective retaining element is altered to meet the tolerance of clamping forces. The difference between the previous position and the altered position is compensated by occupying the other adjusting holes in Chap. VI. Owing to this feature a larger band width is proposed for the tolerance zone for pre-clamping forces of a type of limitation-units. This tolerance zone may be subdivided into, say, ten tolerance classes marked with different colours. On assembly the differences are compensated by occupying one of e.g. 20 adjusting holes $K_1, K_2, .., K_n$. Owing to the other adjusting holes $M_1, M_2, .., M_n$ and $N_1, N_2, .., N_n$ the proper length can be adapted as well as adjusted. Thanks to all these features the reject rate is low, hence, substantially lowering the manufacturing costs.

XI. Cost-saving by pre-assembling the safety device consisting of wires **60 to 62**, pivots **40 to 49** and limitation-units for just-in-time delivery to assembly line.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention will be described in the accompanying drawings with reference to the xyz global coordinate system:

Fig. 1 is a schematic view of a vehicle frame with an power plant **10**, steering wheel **90**, steering column **91** and with the 1st embodiment of a safety device with a pair of independently operating impact elements **5,** whose bearing boxes **30.7** are arranged to the runners and/or transverse girder, and with deformable elements **1**, guide elements **52**, impact pans **5.1**, wires **60 to 62**, delimiters **51**, pivots **40 to 49** and two pairs of energy-absorbing limitation-units **70** in xy-plane.

Fig. 2 is a longitudinally cross-sectional view of a transversely built power-plant **10** with the feature of power-plant displacement ref. to DE 4326396 A1 in the event of front collision and with the 3rd embodiment of a safety device, wherefrom each impact element **5c** with guide element **52a** is arranged to the front portion of runner **30** facing that power-plant and through bearing **58c** of sliding wall **55**.

Fig. 3 is a longitudinally cross-sectional view of a transversely built power-plant **10** ref. to DE 4326396 A1 with the 4th embodiment of a safety device differing from the 3rd embodiment by bearing **58c1** of transverse girder **31** to support impact element **5c1**.

Fig. 3a is a partially enlarged cross-sectional view of bearing **58c** with rubber bush **58.1** to support that impact element **5c1** of **Fig.** 3.

Fig. 4 is a perspective view of runner **30** with crumpling zone Z_c reinforced by additional element **3c** to receive that impact element of **Fig.** 2 and 3.

Fig. 5 is a perspective view of safety device ref. to DE 3801347 C2.

Fig. 6 is a schematic view of a vehicle frame with an power plant **10** and with the 2nd embodiment of a safety device with a pair of independently operating impact elements **5,** whose bearing boxes **30.7a** are arranged in the runners and/or transverse girder, and with impact pans **5.1a**, deformable elements, guide elements and energy-absorbing limitation-units in xy-plane.

Fig. 7 is a perspective view of runner **30** with crumpling zone Z_d reinforced by additional element **3d** to receive impact element **5d** of the 5th embodiment of a safety device.

Fig. 8 is a cross-sectional view of the 6th embodiment of the safety device along the line II-II of **Fig.** 9 to illustrate the process of correcting the distance of f between the blocking ring **51.4a** and holder **51.5a** by clamping a spacer **51.6a** with open profile and length f_1 on the wire **61**.

Fig. 9 is a schematic perspective view of symmetrical half of the 6th embodiment of a safety device with impact element **5a**, wires **60, 61**, guide element **52a,** pivots **44a, 47a, 48** and delimiter **51a**.

Fig. 10 is a schematic perspective view of the runner **30** subdivided into **n** crumpling zones whereamong the crumpling zone Z_b is reinforced by additional element **3b** to receive an impact element **5b** of the 7th embodiment of a safety device.

Fig. 11 is a cross-sectional view of the 1st embodiment of the safety device along the line I-I of **Fig.** 1.

Fig. 12 is a schematic perspective view of the 1st embodiment of an energy-absorbing limitation-unit **70** to pre-tension the seat belts.

Fig. 13 is a schematic perspective view of the 2nd embodiment of an energy-absorbing limitation-unit **80**.

Fig. 14 is a schematic perspective view of the 3rd embodiment of an energy-absorbing limitation-unit **80a**.

Fig. 15 is a cross-sectional view of the 3rd embodiment of the energy-absorbing limitation-unit **80a** in engagement of the retaining hole with the retaining strut **81.2a** along the line III-III of **Fig.** 14.

Fig. 16 is a schematic perspective view of the 4th embodiment of an energy-absorbing limitation-unit **80b**.

Fig. 17 is a cross-sectional view of the 4th embodiment of the energy-absorbing limitation-unit **80b** in engagement of the retaining collar **82.1b** with the retaining notch along the line V-V of **Fig.** 16.

Fig. 18 is a cross-sectional view of the 4th embodiment of the energy-absorbing limitation-unit **80b** in engagement of the retaining collar **82.1b** with the retaining notch along the line IV-IV of **Fig.** 16.

Fig. 19 is a schematic perspective view of the 5th embodiment of an energy-absorbing limitation-unit **80c**.

Fig. 20 is a schematic perspective view of the 6th embodiment of an energy-absorbing limitation-unit **80d**.

Fig. 21 is a schematic perspective view of the 7th embodiment of an energy-absorbing limitation-unit **80e**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The right-hand drive vehicle is represented by the steering wheel **90** drawn in **Fig.** 1 and 5. However, all features are applicable for right-hand drive vehicle as well as for left-hand drive vehicle.

The 1st embodiment of a safety device in **Fig.** 1 differs from the 2nd embodiment in **Fig.** 6 by the positions of the pairs of impact elements **5** and delimiters **51** so only one description is sufficient.

Each impact element **5** with guide element **52** is guided by bearing box **30.7** in **Figs.** 1 and 11. This guide element is

- bolted by bolts **1.7** to the nuts **1.6** of the front plate **1.1** of deformable element **1** and
- provided with a retaining hole to receive and secure the delimiter **51** (see installation in Chap. VII) by connection elements **51.1** and with a strut having a hole serving as pivot **47** to pivotally move and displace the wire **60**.

For pivots **47, 40** and **49** the pivotal roller **44** can be used, however, with additional costs. The wire **61** between roller **44.3** and holder **44.2** is loosely guided by that roller **44.3** secured to that holder by retaining rivet **44.1**. The pivot **46** is the same as pivot **44**. The following parts are rigidly attached

- pivots **42, 43, 45** of the pre-assembled component with wires **61, 62** to the mounting girder **56.1** or a stiff part of passenger compartment **56**,
- pivots **40, 44, 46** to the transverse girder **31** and
- those wires to the pivot **41** consisting of threaded bolt **41.1** and nut **41.2**.

After adjusting the permissible tautness of wire by occupying one of the adjusting holes L_1, L_2, .. , L_n of the respective delimiter **51**, the fork-shaped wire holder **61.1** of wire **61** and wire holder **62.1** (not drawn) of wire **62** are pivotally secured to that delimiter by connection elements **51.2**.

In the 3rd to 7th embodiments without bearing boxes **30.7, 30.7a** in **Figs.** 2, 3, 7, 9 and 10 a pair of impact elements **5a to 5d, 5c1** is arranged in or to the runners **30**. The impact element provided with rubber bush such as **54.1** in **Fig.** 9 is fastened to the reinforced crumpling zone by bolt **54** and nut **54.2**. Riveting or welding is suitable too for form- and/or force-locking connection. The hole of the strut of guide element **52a** serves as pivot **47a** to pivotally move and displace the wire **60**. After adjustment the guide element **52a** is bolted to impact element **5a** by connection elements **52.1**. Costs are saved by extended use of connection elements **52.1** to fasten the wire holder **61.1a** of wire **61** to guide element **52a** in **Fig.** 10.
If the adjustment makes it necessary to occupy another adjusting hole, the wire holder **61.1a** is bolted to impact element **5b** by connection elements **52.1a** in **Fig.** 9. The pre-assembled component with wire **61**, pivots **42, 43, 44a** (similar to **44**), delimiter **51a** and holder **51.5a** in **Figs.** 8 and 9 is assembled in the vehicle by force-locking connection of those pivots with stiff vehicle girders **31, 56.1** and that holder with transverse girder **31**.

Retaining element of energy-absorbing limitation-unit **70, 80, 80a to 80e** in **Figs.** 1, 12 to 21 is attachable to any stiff vehicle girder just like retaining element **81e** to side rail **34** in **Fig.** 21. The element **71.1, 82, 82a to 82c** movable by tension force of wire **60** is provided with site of predetermined fracture "b" for the purpose of limitation. Alternately, the limitation-units **80d, 80e** are provided with delimiters **51d, 51e** having site of predetermined fracture "b". Fracture occurs after the engagement of the retaining parts with each other under load of increasing tension force.

In the 1st embodiment the limitation-unit **70** in **Figs.** 1, 12 comprises a spring element **72,** shock absorber **73** and delimiter **71** consisting of tube **71.1** with retaining notch and retaining element **71.2** with a preloaded retaining plate **71.3** which engages with that retaining notch of the tube moved by tension force of wire **60**.

In the 2nd and 3rd embodiment the limitation-unit **80, 80a** in **Figs.** 13 to 15 comprises an expanding clamping element **82, 82a** and a retaining element **81, 81a**. Both units differ form each other by cylinder- and cone form of clamping elements as well as retaining pair retaining hole / two-sided retaining strut **81.2a** of strut **81.1a**. The gap denoted with s has influence on the spring rate or clamping force and the engagement. For the purposes of loose guidance of the gap by strut **81.1a** and of maximizing the clamping force of clamping element **82a** on the retaining element **81a** the longitudinal gap S_A must be defined by the magnitude of longitudinal gap $s_a > 0$ which may not be too small or too big between the gap shape and strut **81.1a** as well as between the gap shape and retaining strut **81.2a** in longitudinal direction. After projection through the holes of clamping element **82a** and of fork-shaped wire holder **60.2** of belt wire **60.1** (wire **60.1** of seat belt **64**) the blocking pin **60.3** is secured by two securing parts **60.4**. After engagement of that retaining hole with that two-sided retaining strut, restriction by the contact of blocking pin **60.3** with the collar of retaining element under the condition of the distances s_1 and s_2 and after fracture of site of predetermined fracture "b", the pre-tensioning force of seat belts **64** is preserved by the retaining pair.

In the 4th embodiment the limitation-unit **80b** in **Figs.** 16 to 18 comprises a contracting clamping element **82b** and a retaining element **81b**. After projection through the holes of clamping element **82b**, wire holder **60.2a** of belt wire **60.1** and two guide sleeves **60.5a** the blocking pin **60.3a** is secured by two securing parts **60.4a**.

For the purposes of unrestricted guidance of the gap by guide pin **82.2b** and of maximizing the clamping force of clamping element **82b** on the retaining element **81b** the longitudinal gap S_B must be defined by the magnitude of longitudinal gap $s_b > 0$ which may not be too small or too big between the gap shape and guide pin **82.2b** in longitudinal direction.

The cone-shaped chamfer denoted with "a" assists the process of engagement of retaining collar **82.1b** of clamping element **82b** with the retaining notch of retaining element. After the engagement of retaining collar **82.1b** with the retaining notch, restriction by the contact of both guide sleeves **60.5a** of blocking pin **60.3a** with the edges of both side notches of retaining element while preserving the depth of retaining notch of s_3 and after fracture of site of predetermined fracture "b", the pre-tensioning force of seat belts is preserved by the retaining pair.

In the 5th embodiment the limitation-unit **80c** in **Fig.** 19 comprises an expanding clamping element **82c** without site of predetermined fracture, a retaining element **81c**, retaining pair retaining hole / two-sided retaining strut **81.2c** of strut **81.1c** and delimiter **51c** with site of predetermined fracture "b". The preservation of pre-tensioning force of seat belts corresponds to the 3rd embodiment.

After projection through the holes of clamping element **82c,** wire holder **60.2c** of pre-wire **60.1c** and two guide sleeves **60.5a** the blocking pin **60.3c** (similar to **60.3**, hence not drawn) is secured by two securing parts **60.4a**.

In the 6th embodiment the limitation-unit **80d** in **Fig.** 20 comprises a contracting clamping element **82d** without site of predetermined fracture, a retaining element **81d**, retaining pair retaining notch / retaining collar **82.1d** of clamping element **82d** and delimiter **51d** with site of predetermined fracture "b". The preserving operation of pre-tensioning force of seat belts corresponds to the 4th embodiment.

After projection through the holes of clamping element **82d,** wire holder **60.2d** of pre-wire **60.1d** and two guide sleeves **60.5a**, the blocking pin **60.3d** (not drawn) is secured by two securing parts **60.4a**.

In the 7th embodiment the most economical limitation-unit **80e** without retaining and blocking parts in **Fig.** 21 comprises an expanding or contracting clamping element **82e** without site of predetermined fracture, a retaining element **81e** and delimiter **51e** with site of predetermined fracture "b".

As noted hereinabove, the distance between blocking ring **60.7** and holder **60.8** is adjusted by spacer **60.6** and the pre-tensioning force of seat belts **64** is preserved by retaining parts.

Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.